Discrete Dynamical Model of Interspecies Relations of Zooplankton from Lake Sevan in the Period just before the Registration of Population Peaks of Cyanophyta

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Introduction

Global warming states a very wide range of environmental problems of systemic nature, one of which is the need to expand the set of models and methods of mathematical modeling for more detailed and many-sided investigation of behavior of ecological systems. One of the most important properties of system is the structure of relations between the elements (components) of given system. We say about following six types of between-element relations ("zero-zero", "plus-plus", "minus-minus", "plus-minus", "plus-zero", "minus-zero") and three types of intra-element relations ("zero-zero", "plus-plus", "minus-minus").
The method of Discrete Modeling of Dynamic Systems with feedback (DMDS), developed by the Laboratory of adaptive mechanisms modeling and School of Mathematics and Mechanical Engineering of V. N. Karazin Kharkiv National University [1], allows to find the most probable structure of between-element and intra-element relations in multi-component systems of different nature.
Earlier [2] we used this method to simulating certain aspects of the territorial behavior of animals. These aspects can be relevant in connection with the problem of changing their habitats under dramatic climate changes.
The theme of the present work is simulation of the relations structure of zooplankton from lake Sevan (Armenia), which has been suffering an anthropogenic eutrophication within many years due to decreasing water level (large amount of water was pumped for irrigation since 1938) [3]. The consequence of this anthropogenic eutrophication was a growth of Cyanophyta biomass in lake, which was before oligotrophic. It should be noted that the massive growth of Cyanophyta, i. e. "blooming" of water, is now a serious problem and its importance will be increase in connection with global warming.

Methods

For revealing structure of relations the weight functions method of DMDS [1] was used. The data were extracted from the literature [3], described dynamics of zooplankton from lake Sevan for the period of 1937-61 (the number for each year from April to September inclusively). The structure of relations between following species, belonging to main systematic groups of freshwater zooplankton, was simulated:
- Keratella quadrata (Rotatoria);
- Filinia longiseta (Rotatoria);
- Cyclops strennus sevani (Copepoda);
- Daphnia longispina sevanica (Cladocera).

Pearson correlations between the number of geomagnetic field disturbances for given value of Kp-index and zooplankton number for testing working hypotheses (obtained with the help of DMDS) about systemic factors of stability of zooplankton community were calculated. As we mentioned above, the data are extracted from long-term observations [3, 4].

Results

We have revealed the structure of relations between above mentioned species for two subperiods of general period 1937-61. First, more yearly subperiod (1937-57) is related with situation long before Cyanophyta population peaks. Second, more late subperiod (1958-61) is immediately preceding such peaks.

It's convenient to present the structure of inter- and intra-species relations in the form of matrix or graph, but now we present this structure by plain text according to such rules:

1. Relations of type "plus-plus", "zero-minus" and other we shall present in short form (+,+), (0,-) etc.
2. If species A and species B are in relation (s,u), where s and u are admissible relations (namely, +, -, 0), it means that B relates to A as s and A relates to B as u. For example, if species A and species B are in relation (+,-), it means that B has positive influence upon on A and A in turn has negative influence on B (or, in other words, A may be predator to prey B).

Now we can describe the structure of relations for both subperiods for pairs of species.

a) Intra-species relations for Keratella quadrata (0,0), Filinia longiseta (-,-) and Cyclops strennus (0,0) had not changed within two subperiods.

b) Inter-species relations for the following pairs had changed: Filinia longiseta - Keratella quadrata ((0,0) for 1st period, (+,-) for 2nd), Cyclops strennus - Keratella quadrata ((+,-) and (-,+) and correspondingly), Cyclops strennus - Filinia longiseta ((0,0) and (-,0)).

c) The species Daphnia longispina play a important role in a cycle of matter and energy in lake ecosystem, because it filters particles of live and dead organic substance from water. And these cycles are important for forming systemic factors, which determine the possibility of appearance of population peaks of Cyanophyta. In our situation the relations of Daphnia longispina with other species have changed essentially. For the 1st subperiod Daphnia longispina with Keratella quadrata, Filinia longiseta, Cyclops strennus was in relations (+,+), (-,+) and (+,-) correspondingly, for 2nd (-,0), (+,-) and (+,+). Intra-species relations have changed from (-,-) to (0,0).

We can interpret these changes in such a way. Essential feature of relations structure for 1st period (long before population peak of Cyanophyta) is the fact, that homeostasis of Daphnia longispina, along with internal negative feedbacks, is controlled by intra-species concurrence. In contrast to this subperiod, for 2nd one there is no intra-species concurrence. There are known models [5, 6, 7], according to which the inner concurrence in multi-component system furthers its stability. Accordingly, the following working hypothesis can be proposed: zooplankton of lake Sevan for 1st subperiod is more stable to external influences comparative to zooplankton for 2st subperiod. In particular, to such influence as geomagnetic field disturbance. This hypothesis is confirmed by comparison of Pearson correlations between the biomass of Daphnia longispina and the frequency of geomagnetic field disturbances with Kp-index greater or equal to 6 and less 7 for the same months. For mentioned subperiods we can see essential difference. For the 2nd subperiod there is a statistically significant (at the level of 0.05) positive correlation between these parameters, for the 1st the correlation coefficient isn't statistically significant.

Discussions

It should be noted that DMDS is essentially a mean for working hypotheses generation. In the framework of present report the working hypotheses were obtained, which are agree with known facts about relations structure of lake zooplankton. These facts mainly concern relations of concurrence complimented by relations of other types. For example, it's known that Cyclops of adult phase are predators to majority of species Cladocera and Rotatoria, and Cyclops of Nauplii phase are concurrents to these species. Working hypotheses, obtained by DMDS, give an explanation of causes of different

sensitivity of zooplankton to geomagnetic field disturbance in subperiods, differing each from other by the state of lake ecosystem (by presence of population peak of the species Cyanophyta).
The present state of DMDS algorithm allows to reveal relations between very few number of system components (4, 5 or 6), but computers of future generations will allow essentially to increase this number. This dramatically enlarge capacities of DMDS for ecological applications.

Conclusions

Earlier proposed method DMDS demonstrated a practical usefulness for investigation of systemic aspects of such significant phenomenon as population peaks of toxic species Cyanophyta in water reservoirs. In particular, these results has importance for drinking water reservoirs and recreational basins.

References

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